Evolution of cataclysmic variables and related binaries containing accreting white dwarfs

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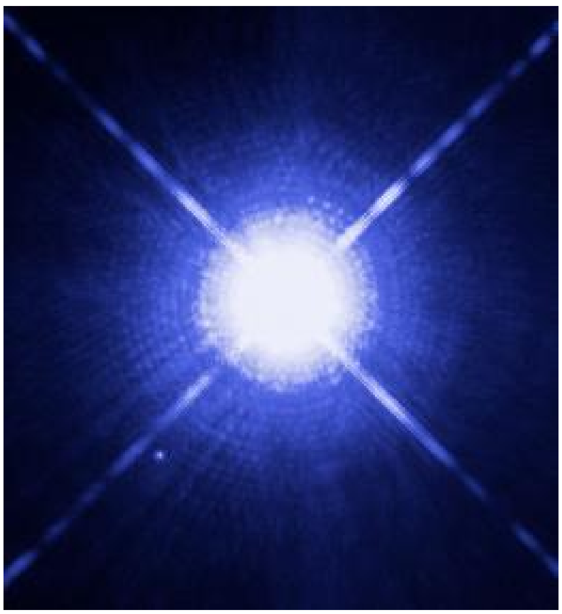

Image of Sirius A and Sirius B taken by the Hubble Space Telescope. Sirius B, which is a white dwarf, can be seen as a faint pinprick of light to the lower left of the much brighter Sirius A. Image: NASA, ESA

About one-half of the stars in our Milky Way galaxy are thought to be in binary systems wherein both stars orbit their common center of mass. If the binaries are formed with the appropriate masses and separations, it is possible for the stars to exchange mass. In other words, the gravitational pull of one of the stars can be so strong that it literally rips the gas from the atmosphere of its companion. These interacting binary systems are some of the most exotic and intriguing astronomical objects in the galaxy and can give rise to a wide variety of phenomena including highly energetic explosions.

Cataclysmic variables (CVs) are a very heterogeneous class of interacting binaries and provide us with some of the most compelling clues as to the formation and evolution of interacting binaries as a whole. CVs are composed of white dwarf stars (about the same size as the Earth but extremely dense) that are cannibalizing a wide variety of companion stars. These companions are most often very ordinary stars such as our Sun, but they can also be giants that have undergone significant (internal) chemical changes as a result of nuclear fusion.

One of the big questions that arises is "can all of the observed CVs and the phenomena associated with them be understood in terms of a single unified picture?" Other questions relate to the relative probabilities that CVs will be observed at particular stages in their evolution, and how the observations of CVs at the current epoch can be used to determine their ultimate fate.

To address these questions Professor Lorne Nelson (Bishop's University) and his collaborators at MIT (Saul Rappaport and Belinda Kalomeni) have undertaken a massive computational effort to theoretically simulate the evolution of most of the possible CVs that could be produced by nature. The temporal evolution of 56,000 nascent CVs was followed over an age of 10 billion years (a Hubble time) using the MESA stellar evolution code. According to Nelson, "This is the most ambitious analysis of the properties of an entire CV population that has ever been undertaken. The whole project required several core-years of CPU time."

While many of the results confirmed what had already been inferred about the properties of CVs, there were a number of surprises including the identification of a number of previously unexplored evolutionary pathways. But, as expected, a sharp bifurcation was found between nascent CVs that evolved to produce double white-dwarf binaries (including ones containing helium and hybrid white dwarfs), and ones that continuously transferred mass over the lifetime of the universe. In addition, observations of CVs with reasonably well-measured properties were in good general agreement with the predictions of the theoretical simulations.

What was surprising was the large number of short-period "ultracompact" binaries (AM CVn stars) that were produced and, especially, the enormous depletion of carbon relative to nitrogen and oxygen that is predicted at certain epochs for evolved systems. As Nelson points out, "It seems that nature has provided us with a unique way to identify CVs that descended from a highly evolved state based on their carbon abundances. There is already some observational evidence to suggest that there is a significant depletion of carbon in certain CVs. This could be a really critical test that will allow us to infer the lineage of some CVs and predict what their fate will be."

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